APPENDIX C

AMD Mitigations Conceptual Designs and Cost Evaluation—Update

AMD Mitigations Conceptual Designs and Cost Evaluation—Update

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1.0 Introduction

1.1 Purpose and Objectives

This technical memorandum presents updated conceptual design development and cost evaluations for acid mine drainage (AMD) mitigation alternatives for the Bunker Hill mine, which were originally presented in Appendix A of the *Draft Preliminary Screening for TMDL Compliance* report (CH2M HILL, February 2000a). The original costs were modified in Appendix A of the *Supplement to the Draft Preliminary Screening for TMDL Compliance* report (CH2M HILL, 2000b). Mitigation options in this memorandum have been revised based on the May 18, 2000, Bunker Hill meeting that is documented in the *Bunker Hill Mine Water FS Alternatives* memorandum (CH2M HILL, 2000c). The revisions are summarized in Table 1 and are described in detail in their respective sections of this technical memorandum. Those that are listed in Table 1 as having no modifications have been included for completeness of all currently considered AMD mitigation alternatives.

1.2 Document Organization

This document is organized into seven main sections:

Section 1. Introduction—This section includes the purpose, objectives, document organization, and limitations of this technical memorandum.

Section 2. West Fork Milo Creek—This section describes AMD mitigation measures that apply to the West Fork Milo Creek drainage basin area. A description is provided for each mitigation measure, along with the design criteria, conceptual design, and costs [both capital and long-term operations and maintenance (O&M)].

Section 3. South Fork Milo Creek—This section describes AMD mitigation measures that apply to the South Fork Milo Creek drainage basin area. Diversion is the only mitigation carried forward for the South Fork. For this mitigation, a description is provided, along with the design criteria, conceptual design, and costs (both capital and long-term O&M).

Section 4. Mainstem Milo Creek—This section presents the conceptual design and costs for the AMD mitigation measures that apply to the Mainstem Milo Creek drainage basin area. A description is provided for each mitigation, along with the design criteria and costs (both capital and long-term O&M).

Section 5. Deadwood Creek—This section presents the conceptual design and costs for the AMD mitigation measure that applies to the Deadwood Creek drainage basin area. Plugging the Inez Shaft is the only mitigation carried forward for Deadwood Creek. A description is provided for this alternative, along with the design criteria and costs (both capital and long-term O&M).

Section 6. Other Areas—This section presents the conceptual design and costs for the AMD mitigation measures that apply to other areas of the Milo Creek drainage basin area. Plugging drill holes is the only mitigation carried forward for other areas of the mine. For this mitigation, a description is provided, along with the design criteria and costs (both capital and long-term O&M).

Section 7. AMD Mitigations Cost Summary—This section presents a summary of the capital and O&M costs developed for each mitigation alternative.

1.3 Limitations

Detailed design has not been conducted on any of the AMD mitigation approaches summarized in this technical memorandum. The mitigation concepts and resulting implementation costs have been developed for comparison with the costs and benefits of other components of what is believed to be a logical presumptive remedy for long-term water management at the Bunker Hill Mine. The conceptual designs are based on existing data only. Limited additional field investigations (installation of eight piezometers at four locations) have been conducted to augment the existing information. These limited investigations and existing data will have to be supplemented for subsequent design development stages of mitigation implementation and cost refinement. Costs have not been included for in-mine performance monitoring associated with any of the mitigation measures.

Order-of-magnitude cost estimates have been prepared based on conceptual designs of AMD mitigation measures. The cost estimates are in January 2000 dollars and do not include escalation. They were prepared using information available at that time and are subject to adjustments in the scope and details of each design. The cost estimates have been prepared for guidance in project evaluation and should be carefully reviewed prior to making specific financial decisions or establishing final project budgets. The actual costs to implement any of the mitigation approaches are expected to vary from the costs shown herein, based on actual labor and material costs, competitive market conditions, final project scope and other variable factors.

2.0 West Fork Milo Creek

This section describes the AMD mitigation measures that apply to the West Fork Milo Creek drainage basin area: West Fork Diversion, Phil Sheridan (Opening Phil Sheridan Raises, Enhanced Phil Sheridan Raise Rehabilitation, and Proposed Drift Construction), and Surface

Diversions Above Guy Cave. Locations of these mitigation efforts within the West Fork are shown in Figure 1. For each mitigation, a description is provided, along with the design criteria, the conceptual design, and the costs (both capital and long-term O&M costs).

One mitigation measure for the West Fork, which appears in Table 1, Cemented Backfill into Homestake/Utz Workings, was screened out due to high costs and expected low effectiveness during the May 18, 2000, Bunker Hill Mine Water Feasibility Study Alternatives Meeting that is documented by the *Bunker Hill Mine Water FS Alternatives* memorandum (CH2M HILL, 2000c).

2.1 West Fork Diversion

2.1.1 Description

The West Fork Milo Creek (West Milo) is a small ephemeral creek located in the upper watershed of the Milo Creek Basin. West Milo flows are primarily the result of spring snowmelt and storm events. As a result of the depression created by the Guy Cave, West Milo Creek flows directly into the underground workings and does not connect with the flows of the Mainstem of Milo Creek. In addition, Hunt (Hunt, 1984) conducted tracer tests within the West Milo drainage that indicated a direct interconnection of the surface flow with the mine workings. The Katherine Fault intercepts West Milo at approximately elevation 3,900 feet (Figure 1). Hunt was unable to discern the amount of infiltration of water into the mine from the Katherine Fault.

To mitigate this drainage into the mine, a diversion structure or multiple structures would be installed in the West Fork Milo Creek to collect flow. The structure would be keyed into bedrock to cut off and intercept alluvial flows. The flows would be transferred into a pipeline via a grated inlet structure and perforated pipe drain buried in the upstream channel that would route water down to the Reed Landing area within the existing Milo Creek channel system. Figures 2, 3, and 4 show the general configuration of the system.

For costing purposes, it is assumed that a single West Fork diversion structure would initially be developed at a location above the Katherine Fault, near the anticipated upstream edge of the influence zone for downward vertical groundwater gradients to the mine workings. This diversion would be used in conjunction with diversion at Phil Sheridan Raise No. 2 to intercept remaining flows from the West Fork. Because the primary purpose of the diversion is to intercept surface runoff from snowmelt conditions, it is considered important to be able to intercept surface water as well as flow in the alluvial zone above bedrock. Thus, a primary focus for determining the exact siting of the diversion structure will be to locate a point along the stream where bedrock is closest to the ground surface, and where an alluvial cutoff could most easily and effectively be accomplished. In the future, additional foundation grouting of the underlying bedrock beneath the diversion structure could be undertaken if it is determined that fracture grouting would be cost-effective.

Additional diversions could also be considered in the future if necessary, to be located between the initial diversion structure and Raise No. 2, depending on how successful the diversions prove to be. Figure 2 depicts the location of the proposed diversion and the relative position of the Phil Sheridan Adit, Katherine Fault, recent monitoring well borings, and the Guy Cave Area. The secondary diversion at Raise No. 2 is discussed in Section 2.2.

An access road would be required to the dam site for construction and maintenance. It is assumed that the road would be constructed at a grade of about 10 percent. It also is assumed that the access road would tie into the Kellogg Ski Area road that presently crosses that drainage basin above the dam site. This installation would require the construction of about 3,500 feet of new access road (Access Road B). Other Access Road B alignments are possible and could combine sidehill diversions with a road-side ditch. Water collected in the road-side ditch would be diverted directly into the West Fork Diversion screen structure and pipeline diversion system. Other road alignments will be considered during remedial design efforts.

2.1.2 Design Criteria

General design criteria for the West Fork diversion system are as follows:

- Capture alluvial flow and surface flow that comes from drainage basin areas above the diversion location
- Provide capacity to handle the 100-year rainfall event with snowmelt
- Locate the diversion close to the upgradient edge of the mine workings influence zone on groundwater, and locate the structure at a point along the stream where bedrock is closest to the ground surface.
- Minimize potential for plugging of the inlet structure by providing a perforated collector pipe and substantial reserve for the cross-sectional screen area.
- Provide system inflow redundancy
- Convey diversion water from West Milo down to the Reed Landing diversion structure on Mainstem Milo Creek
- Maintain hillside stability and minimize hillside erosion from pipeline construction
- Establish access to diversion dam / intake for maintenance
- Minimize inspection and sediment removal from intake area
- Minimize disturbance in the watershed (roads and logging) above the diversion structure in order to minimize runoff and sediment transport
- Minimize other system maintenance
- Maintain hydraulic profile for proper flow conveyance
- Maintain pipeline stability and structural integrity

Surface Water Flow Estimates

A conceptual design for the West Milo diversion system was presented in a memorandum, *AMD Mitigations Evaluation*, dated July 28, 1999 (part of the presumptive remedy document, CH2M HILL, 1999). Design flows were developed for West Milo in the *Milo Gulch Flood Hydrology and Water Quality Improvement Plan* (Spectrum Engineering, 1996). The design flows include both rainfall events and rainfall events with snow melt. These are summarized in Table 2.

These flow rates are estimated for the entire West Milo basin that drains into the Guy Cave Area. The specific location of the West Fork Diversion structure will be determined during remedial design. The areas currently considered are elevations between 3,900 and 4,100 feet above mean sea level (famsl). The assumed location of the diversion for this analysis is at an elevation of 4,035 famsl, and would capture about two-thirds of the total drainage basin area.

CH2M HILL performed additional hydrologic modeling, based on the proposed position of the West Fork diversion shown in Figure 1, in order to refine anticipated sub-basin flows to the diversion structure. Hydrologic modeling was conducted using HEC1 developed by the U.S. Army Corps of Engineers. A detailed description of the model and the assumptions used in developing the model are presented in Attachment A to this technical memorandum. Results of the modeling are shown in Table 3.

In the July 1999 mitigation evaluation memorandum, the design criterion for the diversion was proposed to be the 5-year rainfall event with snowmelt or the 25-year rainfall-only event, whichever was greater. CH2M HILL recommends upgrading the design to accommodate the 100-year rainfall event with snowmelt. Reasons for the upgrade include:

- Nearly 100 percent of the water from West Milo infiltrates the acid-producing areas of the mine, based on recent reconnaissance efforts.
- Mine flushing events could occur if the diversion capacity was exceeded. Such events could significantly reduce the effectiveness of the mitigation for reducing metal load to the Central Treatment plant (CTP).

Diversion Pipeline Design Criteria

Preliminary sizing of the West Milo diversion pipeline was based on the 100-year, 24-hour rain event with snowmelt flow of 57 cubic feet per second (cfs). Specific pipeline design criteria are as follows:

- Pipe material—welded high-density polyethylene (HDPE), dimension ratio (DR) of 17.
- Pipe diameter—Manning's open channel flow model was used to calculate minimum pipe diameters (n value of 0.011 for HDPE pipe) to carry the anticipated flows.
- As a conservative measure for this conceptual design, the design diameters were increased one to two standard pipe sizes above the minimum size, which were calculated using Manning's model.

2.1.3 Conceptual Design

West Fork Diversion Structure

The West Fork Diversion consists of the construction of a small dam to impound water from the stream and an inlet/screen structure to collect and screen water before it enters the pipeline, as shown in Figures 3 and 4. The diversion dam should extend to bedrock, as required to cut off groundwater flow in the alluvium. Based on borings from piezometers recently installed near the proposed diversion location, the depth to bedrock is estimated to range from about 20 to 40 feet below the ground surface. It is assumed that a backhoe would be used to trench to bedrock or close to bedrock to remove large rock. The trench would be backfilled with a material suitable for driving sheet piling through. The sheet piling would be driven to refusal at the rock surface. Seepage could be further controlled by trenching a foot or more into rock and concrete encasing the base of the sheets in the rock surface, if the depth to rock is about 20 feet or less. If the depth to rock is more than 20 feet, grouting from the ground surface could later be performed to further control seepage past the dam, if warranted. If the depth to rock is greater than 20 feet, then use of a grout curtain may be more cost-effective. A grout curtain would most likely consist of three rows of staged grout holes, with the spacing split down until the grout take is minimal (estimated at 5- to 10-foot spacing). Some grouting of the upper bedrock also may be warranted if it is found to be fractured and pervious.

The dam would be designed for emergency overtopping if the flow should exceed the design hydraulic capacity of the pipeline or the inlet structure becomes clogged. The central portion of the dam would be constructed as a weir, with a slightly lower elevation than the abutments on either side. The downstream side of the dam would be constructed with riprap or grouted riprap for erosion protection.

A screen diversion structure would be located immediately upstream of the dam. The diversion pipeline would connect into a rectangular to round hydraulic transition at the downstream end of the screen diversion structure. The screen diversion structure would be sized for reserve screen area to account for conservative assumptions for clogging. Experience has shown that the most significant maintenance issue would probably be associated with natural accumulation of sediment bed load in the vicinity of the intake. The accumulation of sediment would in time block and/or partially clog the screened opening to the collection chamber. This condition is often appreciably affected by grading, road building, logging and other similar activities in the drainage area above the screen intake area. Grading and construction activities in the drainage basin are beyond the control of this project, but it is assumed that these concerns will be conveyed to the owner of the property and access roads and other construction will be carried out in a manner that minimizes this concern.

A slotted collection pipeline should be installed upstream of the screen intake structure. The purpose of the collection pipeline is to collect most of the surface water in the stream at points upstream of the screen structure. The sediment bed load in the stream can be expected to drop out as the flow in the stream diminishes through infiltration into the slotted pipe, thereby allowing most of the sediment to collect along the stream bed upstream of the screen structure. The slotted pipe would be installed in a shallow trench (2 to 3 feet of cover) and backfilled with clean, gap-graded pea gravel. A series of gabion sediment traps would also be installed along the streambed upstream of the screen structure to further encourage infiltration and collection of sediment at points upstream of the screen structure. Refer to Figures 3 and 4 for typical sections of the dam and screen intake structures.

An access road to the dam site would be required for construction and maintenance. The permanent road should be a minimum of about 12 feet wide and ditched as required to control surface runoff. It is assumed that the road would be constructed at a grade of about 10 percent. It also is assumed that the access road would tie into the spur road off the Kellogg Ski Area road that presently crosses the drainage basin above the dam site. This installation would require the construction of about 3,500 feet of new access road.

A steep access road also would be available along the pipeline route during construction. The slope of this road is estimated to be as steep as about 22 percent and the road would tie into the Guy Cave access road in the West Fork Milo Creek basin.

Diversion Pipeline

A 30-inch-diameter HDPE pipe carrying an anticipated maximum flow rate of 57 cfs would begin at the diversion structure (4,035 famsl), as shown in Figure 1, and would be routed down a newly constructed road to an area adjacent to Raise No. 2. In this area, the pipeline would be routed down Access Road A (see Figure 1) to approximately 3,650 famsl where it would drop into a standard U.S. Bureau of Reclamation stilling basin at the confluence with the Phil Sheridan pipeline, as discussed in Section 2.2.1. The combined, energy dissipated flows (maximum flow rate of 97 cfs) would enter a 36-inch-diameter HDPE pipe at the discharge point of the stilling basin and would generally align northeast, dropping approximately 180 feet into the second stilling basin in the area of the Lower Guy Cave (3,470 famsl). The 36-inch-diameter pipeline alignment would continue northeast down Access Road A where it would drop into a third stilling basin at approximate elevation 3,360 famsl before surfacing at 3,170 famsl and discharging into an HDPE overland pipe 150 feet long and 36 inches in diameter.

The overland pipe would be laid directly on the ground surface and would be anchored at the top (3,170 famsl) by a concrete block. At the bottom of the overland pipe Section (3,125 famsl), an HDPE slip pipe 42 inches in diameter would be anchored at the bottom and laid uphill, overlapping the overland pipe by approximately 15 feet. This slip pipe would provide coverage of the overland pipe during thermal movements of expansion and contraction and would provide enough length to catch back-splashing. A slip gasket would be installed at the upstream end of the slip pipe to prevent soil and debris from entering along the annulus between the two pipes. The overland pipe would then discharge into a fourth stilling basin. The overflow from the stilling basin would discharge into the Reed Landing Dam on Mainstem Milo Creek.

2.1.4 Costs

The cost analysis for the West Fork Diversion was performed on the basis of information contained in U.S. Environmental Protection Agency (EPA) guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. Net present value (NPV) for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in development of the cost estimate for the West Fork Diversion include:

- Design and construction of a 3,500-foot access road routed from the spur road off the Kellogg Ski Hill Area road
- Design and construction of a West Milo Diversion structure, including the dam, foundation cutoff provisions (both a sheetpile and a grout curtain), intake screen, and transition structure
- Design and construction of the upstream collector pipe and gabions

- Design and construction of a 3,350-foot pipeline routed from the diversion structure down to the Reed Landing Dam
- Installation of four standard U.S. Bureau of Reclamation stilling basins to dissipate water energy along the entire length of the pipeline from the diversion structure down to the Reed Landing Dam
- Costs for the West Milo Diversion to the confluence with the Phil Sheridan Diversion pipeline and from the confluence to the Reed Landing Dam are included
- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for the West Milo Diversion are shown in Table 8 in Section 7 of this memorandum. The cost estimate data sheets for West Milo Diversion are provided in Attachment B of this memorandum.

2.2 Phil Sheridan

This section describes the AMD mitigation alternatives that apply to the Phil Sheridan and ultimately to the West Fork Milo Creek drainage basin area. Two alternatives are considered in This section. The first is rehabilitation of the Phil Sheridan Diversion, which includes opening the raises, and installation of a new drift and diversion pipeline. The second alternative is an additional improvement to Phil Sheridan Raise No. 2 that includes provisions for an alluvial flow cutoff wall.

2.2.1 Rehabilitate Phil Sheridan Diversion

This section describes the AMD mitigation measures for rehabilitating the Phil Sheridan Diversion, including opening Phil Sheridan Raises No. 1 and No. 2, and constructing a new drift and diversion pipeline.

2.2.1.1 Description

Open Phil Sheridan Raises

There are three Phil Sheridan raises. Raises No. 1 and No. 2 are completed to the surface, but the surface expression of Raise No. 3 has not been confirmed. As shown in Figure 1, Raise No. 2 is located about 650 feet downstream along West Fork Milo Creek from the proposed diversion structure. Raise No. 1 is located about 200 feet north of Raise No. 2 and captures flow from areas that are outside of the drainage basin captured by the West Fork Diversion.

Sediment and other materials that have collected in Raises No. 1 and No. 2 would be removed to allow surface water flows that reach the raises to flow down to the Phil Sheridan Adit. Surface collection structures would be built to direct flow to Raises No. 1 and No. 2.

As discussed in Section 2.1, Raise No. 2 lies downstream of the West Fork Diversion; thus, flows to this raise would be significantly reduced by the diversion. In conjunction with the upper diversion dam, Raise No. 2 would serve to catch runoff from portions of the watershed outside of the boundaries of the upper diversion. At Raise No. 1, it is anticipated that this raise could be built to also collect flows from the new Sidehill Diversion constructed above the Guy Cave Area, as discussed in Section 2.3. As a result of these diversions, flows to Raise No. 1 could be significantly increased as compared to existing flows currently collected by the structure.

Drift Construction

As previously mentioned (CH2M HILL, 2000a), several cracks in the floor and sides of the Phil Sheridan Adit were observed. In addition, there is considerable uncertainty about the stoping below the Phil Sheridan, and its related safety. These issues have instigated several safety concerns for accessing and constructing a pipeline diversion system in the area of the Phil Sheridan portal as previously proposed (CH2M HILL, 2000a), and has prompted the alternative of advancing a new adit to intersect with the Phil Sheridan Adit. The intersection of the new adit with the Phil Sheridan Adit is approximately 250 feet north of Raise No. 1. The location of the proposed adit portal and its alignment is shown in Figure 1.

During remedial design of the new drift, locations for new raises to capture additional surface water flow should be considered.

2.2.1.2 Design Criteria

General design criteria for rehabilitating the Phil Sheridan Diversion are as follows:

- Minimize hillside erosion in areas of new construction
- Minimize underground and raise maintenance
- Capture surface flow from drainage basin areas within the West Fork drainage basin that will not be captured at the diversion location
- Provide capacity to handle the 100-year rainfall event with snowmelt
- Minimize potential for plugging of inlet structure by providing substantial reserve for the cross-sectional screen area.
- Minimize disturbance in the watershed (roads and logging) above the diversion structure in order to minimize runoff and sediment transport
- Establish access to diversion dam for maintenance
- Convey diversion water from the Phil Sheridan raises down the newly constructed drift and into a U.S. Bureau of Reclamation stilling basin at the confluence with the West Fork Diversion pipeline
- Maintain a hydraulic profile for proper flow conveyance
- Maintain pipeline stability and structural integrity
- Conceptually design the diversion pipeline to accommodate 100-year rainfall event with snowmelt for Raise No. 2 and Raise No. 1 with Sidehill Diversion, which is the largest combined flow that would be anticipated from the Phil Sheridan diversion system

Surface Water Flow Estimates

Hydrologic modeling performed as part of the West Fork Diversion evaluation also modeled stormwater flows that would access Raise No. 2, assuming that the West Fork Diversion was in place, and Raise No. 1, both with and without Sidehill Diversion (discussed in Section 2.3). Modeling was conducted using HEC1 developed by the U.S.

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Army Corps of Engineers. A detailed description of the model and the assumptions used in developing the model are presented in Attachment A of this technical memorandum. Results of the modeling are shown in Tables 4 and 5.

As with the West Fork Diversion, CH2M HILL recommends using the 100-year rainfall event with snowmelt design flows for sizing the diversion structures and conveyance pipelines for the Phil Sheridan Raises.

Diversion Pipeline

Preliminary sizing of the Phil Sheridan diversion pipeline was based on the combined 100-year rainfall event with snowmelt for Raise No. 1 with Sidehill Diversion (Table 5) and Raise No. 2 (see Table 4), yielding a combined flow of 40 cfs. Specific pipeline design criteria are as follows:

- Pipe material—welded HDPE, DR of 17.
- Pipe diameter—Manning's open channel flow model was used to calculate minimum pipe diameters (*n* value of 0.011 for HDPE pipe) to carry the anticipated flows.
- As a conservative measure for this conceptual design, the design diameters were increased one to two standard pipe sizes above the minimum size, which were calculated using Manning's model.

2.2.1.3 Conceptual Design

Open Phil Sheridan Raises

Figure 1 provides the overall locations of the Phil Sheridan Adit and Raises No. 1 and No. 2. The concept requires opening up both raises down to the Phil Sheridan Adit. The raises have filled in over time with rock, sand, and debris from the Phil Sheridan Adit to the ground surface. It is assumed that the raises would be opened by rehabilitating the inlet and by mining from below. These raises were partially cleaned out from the surface in 1999.

For Raise No. 2, a steel casing pipe would be installed from the ground surface through the overburden zone to control future cave-ins. A screen structure would be constructed on the top and sized conservatively to allow for the possibility of some clogging. Some re-grading would be required to enlarge the existing openings, grade to the proper elevations, and provide erosion protection around the intake structure. Figure 5 shows a schematic view of the raise and its components as described.

Rehabilitation of Raise No. 1 is similar to Raise No. 2. A steel casing would be installed from the top of bedrock to the ground surface, and a screen structure would be provided at the top of the casing pipe.

Drift Construction

The construction of the proposed drift would start at an elevation of approximately 3,670 famsl and would be advanced using typical underground drilling techniques for approximately 300 feet at a slope of 1 percent to intersect with the Phil Sheridan Adit as shown in Figure 1. A new access road (approximately 150 feet in length) from Access Road A to the area of the proposed drift portal would need to be constructed and maintained. It is assumed that the new drift would be constructed with the same dimensions as the Phil Sheridan Adit (approximately 8 feet wide by 10 feet tall).

The pipeline would require a partial bulkhead located just upstream of the confluence of the Phil Sheridan Adit to force the water into the pipeline for diversion. The bulkhead would consist of a rectangular concrete collar around the perimeter of the adit with a steel plate and gasket bolted to the concrete collar. The steel plate would in turn attach to a collar on the pipeline to form a watertight connection. A bolted bulkhead door could be provided for entry past the bulkhead for periodic inspection during periods when flow was not occurring. Provisions for air exchange to the back of the drift will be needed.

It is expected that a build-up of sand and other granular debris could occur over a period of time upstream of the bulkhead. This build-up is not expected to cause a serious maintenance problem, but it could result in the accumulation of several feet of sedimentation in the bottom of the 8-foot-wide adit. Although not included in this estimate, alternate provisions to reduce this maintenance could include the construction of a shotcrete or concrete lined, sloping, low-flow channel in the center of the base of the adit. The goal of this concept would be to keep the velocity of the water higher to allow transport of the sediment into the pipe and through the diversion system.

Diversion Pipeline

Collected stormwater would be diverted into a HDPE pipeline 42 inches in diameter by a steel bulkhead located just upstream of the confluence with the proposed drift. The pipeline would rest on the floor of the adit from the bulkhead to the portal (3,670 famsl). At the portal, the pipeline would transition into a HDPE pipe 36 inches in diameter and would be buried in the newly constructed staging area roadway to Access Road A (approximately 150 feet) where it would drop into a U.S. Bureau of Reclamation stilling basin at the confluence with the West Fork Diversion pipeline (3,650 famsl).

2.2.1.4 Costs

The cost analysis for rehabilitating Phil Sheridan Diversion was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate to rehabilitate Phil Sheridan Diversion:

- Opening of Phil Sheridan Raise No. 1 and Raise No. 2 and site grading
- Construction of casing and screened intake structure
- O&M costs include annual inspection and road maintenance and repairs
- Construction of a 300-foot drift starting at 3,670 famsl and intersecting the Phil Sheridan Adit with a bulkhead dam to divert water into the Phil Sheridan Diversion pipeline
- Design and construction of the Phil Sheridan Diversion pipeline beginning inside the drift at the bulkhead dam and routed toward the U.S. Bureau of Reclamation stilling basin at the confluence with the West Fork Milo Creek diversion pipeline

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- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for opening Phil Sheridan Raises No. 1 and No. 2 are summarized in Table 8 in Section 7. Costs for opening Phil Sheridan Raises No. 1 and No. 2 are provided in more detail in Attachment B of this technical memorandum.

2.2.2 Improve Phil Sheridan Raise Rehabilitation

This section describes the improved Phil Sheridan Raise No. 2 rehabilitation effort through installing a grout curtain cutoff wall.

2.2.2.1 Description

As an addition to rehabilitating the Phil Sheridan Diversion, as described in Section 2.2.1, and to enhance water collection by Phil Sheridan Raise No. 2, a grout curtain or similar cutoff mechanism is needed. It is suspected that groundwater currently travels around the raise and eventually infiltrates into the lower mine workings. This barrier would catch a significant portion of the alluvial water from the natural drainage and divert it into Raise No. 2 to eventually be routed along the existing Phil Sheridan Adit, through the new drift, and into a pipeline leading to the West Fork Milo Creek diversion pipeline.

2.2.2.2 Design Criteria

General design criteria for groundwater collection enhancement of the Phil Sheridan Raise diversion system are as follows:

- Capture alluvial flow that enters into Phil Sheridan Raise No. 2
- Divert alluvial flow in the vicinity of Raise No. 2 down to the West Fork Milo Creek diversion pipeline and eventually to the Reed Landing Dam on Mainstem Milo.

2.2.2.3 Conceptual Design

In order to collect groundwater flow near the bedrock surface, a cutoff is needed below Raise No. 2. It is assumed that the cutoff will consist of 90 feet of sheetpile extending from ground surface to top of bedrock (assumed 20 feet) and a grout curtain immediately downstream of Raise No. 2. The grout curtain is assumed to be about 90 feet long, transverse to the stream, and would require three parallel rows of grout holes drilled on about 10-foot staggered centers to a depth of about 50 feet. Perforated collection pipe would be installed in deep trenches upstream of the cutoff to provide drainage back to Raise No. 2.

No provision for cutoff to bedrock was assumed for Raise No. 1. It is assumed that the surface ditch along a new diversion road, as mentioned in Section 2.1, would be used primarily to intercept surface runoff during high runoff events, and would collect water that in turn would be diverted directly into Raise No. 1. In the future, a cutoff could be added if it was determined that a groundwater cutoff provision was needed.

2.2.2.4 Costs

The cost analysis for improved Phil Sheridan Diversion Rehabilitation was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for the improved Phil Sheridan Raise Rehabilitation effort include:

- Placement of a 90-foot-long sheetpile wall transverse to the stream bed
- Placement of three parellel 90-foot-long grout curtains (grout holes 10 feet on center)
- Installation of a perforated collector pipe laid in trenches on top of bedrock for Raise No. 2 (assuming bedrock 20 feet or less below ground surface)
- O&M costs include annual inspection

Order of magnitude costs for enhanced Phil Sheridan Raise Rehabilitation are summarized in Table 8 in Section 7. Costs for enhanced Phil Sheridan Raise Rehabilitation are provided in more detail in Attachment B of this technical memorandum.

2.3 Sidehill Diversions Above Guy Cave

2.3.1 Description

A road would be constructed above the caving area to intercept surface flows coming down the hillside to the Guy Cave or into fissures above the Guy Cave. A lined ditch on the inside of the road would be designed to carry flow along the road grade and discharge to the diversion at the Phil Sheridan Raise No. 1 or to tie into the West Fork Milo Creek diversion pipeline, if constructed. For the purposes of this conceptual design, it is assumed that the ditch flows will be diverted into Raise No. 1. Conceptual location of the hillside diversion is shown in Figure 1. The road adjacent to the ditch would be used for ditch maintenance; a turnaround would be located at the north end of the road for maintenance vehicles.

If additional surface water flow needed to be captured, Sidehill Diversions Above Guy Cave would be constructed in conjunction with the Raise No. 1 improvements. A screened intake structure would be provided along the nearby diversion road, and a short pipe would connect from the ditch intake structure directly to Raise No. 1.

2.3.2 Design Criteria

General criteria for this mitigation are as follows:

- Provide capacity to handle the 100-year rainfall event with snowmelt
- Reduce inflow to Guy Cave Area from overland flow sources by collecting water with a screened intake structure along the ditch and conveying it to the Phil Sheridan Raise No. 1
- Minimize channel velocity along the ditch
- Provide a ditch lining to enhance collection and retention of water in the ditch
- Minimize hillside erosion
- Provide access for maintenance/clean-out along the ditch

Surface Water Flow Estimates

Hydrologic modeling was performed for this option to determine the capacity necessary for surface ditches to capture overland flow that would otherwise flow into the Guy Cave. Modeling included stormwater flows captured by the sidehill ditch alone, as well as combined flows with Raise No. 1. Modeling was conducted using HEC1 developed by the U.S. Army Corps of Engineers. A detailed description of the model and the assumptions used in developing the model are presented in Attachment A to this technical memorandum. Results of the modeling are shown in Table 5.

As with the previous West Fork mitigations, CH2M HILL recommends using the 100-year rainfall event with snowmelt design flows for the sizing the Sidehill Diversion Ditch and conveyance pipelines.

2.3.3 Conceptual Design

This alternative requires the construction of about 940 feet of hillside road above the Guy Cave Area. The road would be laid out at about a 10 percent grade and is located as shown in Figure 1. Figure 6 provides a typical cross section of the road showing the ditch liner, cut slope, cross slope for the road, and liner and road surfacing materials.

The screen diversion structure would be constructed in the ditch at a point near Raise No. 1. The screen diversion would convey the water collected in the ditch into a pipe and into the vertical raise. If the screens become clogged, the water would flow over the road and down the slope to the nearby raise location where it would pass through a cone screen at the top of the steel casing installed in the raise.

The construction of a cutoff or grout curtain has not been assumed to be required at the Raise No. 1 location, because it is not located in a drainage swale where appreciable subsurface alluvial flows are known to exist. The remaining elements of this diversion (Phil Sheridan Raise No. 1 improvements) are described in Section 2.2.

2.3.4 Costs

The cost analysis for the Sidehill Diversions Above Guy Cave mitigation was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for Sidehill Diversions Above Guy Cave include:

- Installation of a ditch lining system
- Need for control of erosion and sedimentation
- Design and construction of a screen intake structure
- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for hillside diversions are summarized in Table 8 in Section 7. Costs for the Sidehill Diversions Above Guy Cave are provided in more detail in Attachment B of this technical memorandum.

3.0 South Fork Milo Creek

This section presents the conceptual design and costs for the AMD mitigations that apply to the South Fork Milo Creek drainage basin area. A single mitigation is identified in Table 1 for the South Fork—the South Fork Diversion. Figure 1 shows the location of this mitigation within the South Fork Milo Creek drainage basin. For this mitigation, a description is provided, along with design criteria, the conceptual design, and costs (both capital and long-term O&M).

3.1 South Fork Diversion

3.1.1 Description

The South Fork Milo Creek is a steep mountain stream that is ephemeral in its upper reaches and perennial for approximately 700 feet above its confluence with the Mainstem of Milo Creek. South Fork Milo Creek is spring-fed from a talus slope that extends up Kellogg and Wardner peaks. As shown in Figure 1, the Cate and Buckeye faults cross South Fork Milo Creek in the portion of the creek that is perennial, with the Katherine Fault crossing the creek further upstream in its ephemeral stretch.

The concept that was evaluated requires the diversion of South Fork Milo Creek from above the Buckeye fault zone (in the portion of the creek's length that is perennial). From there it would be hard-piped to the Reed Landing Dam. Another option, not evaluated, would be to pipe the flow only to the existing upper diversion that was constructed in Mainstem Milo Creek in 1998. At this point, the water would be piped into the existing pipeline or a new line extending downgradient from that point. This option was not evaluated; using a 10-year rainfall event with snowmelt for design of the South Fork diversion, the existing pipeline is undersized for this capacity.

3.1.2 Design Criteria

General design criteria for the South Fork diversion system are similar to those for the West Fork diversion and include:

- Capture alluvial flow and surface flow that comes from drainage basin areas above the diversion location
- Provide capacity to handle the 10-year rainfall event with snowmelt
- Locate the diversion at or above the influence zone for groundwater entering the underground mine workings
- Minimize potential for plugging of the inlet structure by providing a perforated collector pipe and substantial reserve for the cross-sectional screen area.
- Provide system inflow redundancy

- Convey diversion water from South Fork Milo Creek down to the Reed Landing diversion structure on Mainstem Milo Creek
- Provide energy dissipation at pipeline discharge
- Maintain hillside stability and minimize hillside erosion from pipeline construction
- Establish access to diversion dam / intake for maintenance
- Minimize inspection and sediment removal from intake area
- Minimize disturbance in the watershed (from road construction and logging) above the diversion structure in order to minimize runoff and sediment transport
- Minimize other system maintenance
- Maintain hydraulic profile for proper flow conveyance
- Maintain pipeline stability and structural integrity

South Fork Milo Creek Design Flow Rates and Pipe Sizing

Initial pipeline sizing was completed based on available hydrology information developed by others. The intent is to size the pipeline for a storm with a reasonable return period that will allow most of the annual flow in the South Milo Creek watershed to be collected and conveyed to bypass the mine workings.

A conceptual design for the South Fork Milo Creek diversion system was presented in the memorandum *AMD Mitigations Evaluation*, dated July 28, 1999 (part of the presumptive remedy document, CH2M HILL 1999a). Design flows were developed for South Fork Milo Creek in the *Milo Gulch Flood Hydrology and Water Quality Improvement Plan* (Spectrum Engineering, 1996). The design flows included both rainfall events and rainfall events with snowmelt. These events are summarized in Table 6.

These flow rates are estimated for the entire drainage basin of South Fork Milo Creek. The proposed diversion would be located upstream in the South Fork Milo Creek basin and would thereby reduce the contributing area of the basin slightly from these numbers. In the case of the South Fork Milo Creek drainage area, with the diversion located approximately at elevation 3,510, about 75 percent of the drainage basin is above this diversion location. Because the higher elevations in the basin represent the source of snowmelt, using the estimated flows from the Spectrum report (Spectrum Engineering, 1996) to initially size the diversion pipelines seems reasonable without being overly conservative.

CH2M HILL proposes sizing the pipelines from the diversions to convey the 10-year rainfall with snowmelt storm event. These flows are larger than the previous recommendation of the 5-year event with snowmelt event as presented in the memorandum *AMD Mitigations Evaluation* (part of the presumptive remedy document, CH2M HILL, 1999). The recommendation to increase design flows to the 10-year event is based on the desire to reduce the frequency of bypass flows in the South Fork Milo Creek that could access mine workings, in conjunction with looking at the cost increase of the diversion structure and conveyance pipeline for the higher flows. The 100-year design flow used for the West Fork Diversion was considered to be too extreme, and therefore too costly, for the larger South Fork Milo Creek drainage system, particularly considering that a smaller percentage of the South Fork flows reach lower mine workings via the localized fault system (in comparison to the West Fork Diversion). The creek diversion structure would be designed so flows associated with larger storm events would be bypassed without damage to the diversion structure.

The discharge pipeline design criteria identified for the South Fork Milo Creek Diversion are as follows:

- Pipe material—welded HDPE, DR of 17
- Pipe diameter —Manning's open channel flow model was used to calculate minimum pipe diameters (*n* values of 0.011 for HDPE pipe) to carry the anticipated flow
- As a conservative measure for this conceptual design, the design diameters were increased one to two standard pipe sizes above the minimum size, which were calculated using Manning's model.

3.1.3 Conceptual Design

South Fork Diversion Structure

The South Fork Diversion consists of construction of a small dam to impound water from the stream and an inlet/screen structure to collect and screen water before it enters the pipeline. The diversion dam/cutoff system should extend to bedrock as required to cut off groundwater flow in the alluvium. Based on observations in the area, it is likely that the depth to the rock surface in this area is less than 20 feet. Therefore, it is assumed that a backhoe would be used to trench to bedrock for forming a seepage cutoff. The trench would be backfilled with a material suitable for installing or driving sheet piling in. The sheet piling would be driven to refusal at the rock surface. Seepage could be further controlled by trenching a foot or more into rock, encasing the base of the sheets in concrete at the rock surface (if necessary), and performing foundation curtain grouting of the bedrock

The dam would be designed for emergency overtopping if the flow exceeds the design hydraulic capacity of the pipeline or the inlet structure becomes clogged. The central portion of the dam would be constructed as a weir having a slightly lower elevation than the abutments on either side. The downstream side of the dam would be constructed with riprap or grouted riprap for erosion protection.

A screen diversion structure would be located immediately upstream of the dam. The diversion pipeline would connect into a rectangular to round hydraulic transition at the downstream end of the screen diversion structure. The screen diversion structure would be sized for reserve screen area to account for some clogging. Experience has shown that the most significant maintenance issue would probably be associated with natural accumulation of sediment bed load in the vicinity of the intake. The accumulation of sediment would in time block and/or partially clog the screened opening to the collection chamber. This condition is often appreciably affected by grading, road building, logging, and other similar activities in the drainage area above the screen intake area. Grading and construction activities in the drainage basin are beyond the control of this project, but it is assumed that these concerns would be conveyed to the owner of the property and access roads and other construction would be constructed in a manner that minimizes this concern.

A slotted collection pipeline would be installed upstream of the screen intake structure. The collection pipeline would collect most of the surface water in the stream at points upstream

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of the screen structure. The sediment bedload in the stream can be expected to drop out as the flow in the stream diminishes through infiltration into the slotted pipe, thereby allowing most of the sediment to collect along the streambed upstream of the screen structure. The slotted pipe would be installed in a shallow trench (2 to 3 feet of cover), and backfilled with clean, gap-graded pea gravel. A series of gabion sediment traps would also be installed along the streambed upstream of the screen structure to further encourage infiltration and collection of sediment at points upstream of the screen structure. The diversion structure, including dam and screen intake, for South Fork Milo Creek will be similar to the diversion structure for West Fork Milo Creek, as shown in Figures 3 and 4.

An access road to the dam site would be required for construction and maintenance. The permanent road should be a minimum of about 12 feet wide and ditched as required to control surface runoff.

Diversion Pipeline

The diversion pipeline (36-inch-diameter HDPE) would start at the South Fork Diversion Structure (3,530 famsl) and align north-northeast for approximately 550 feet, where it would drop into a U.S. Bureau of Reclamation stilling basin at 3,390 famsl. The discharge of the stilling basin would enter another 36-inch-diameter HDPE pipeline, cross Mainstem Milo Creek, and would then turn north-northwest, crossing the existing 36-inch-diameter corrugated metal discharge pipeline for the Upper Milo Diversion Dam. In this area, the pipeline would be constructed in a new grade to be established by benching into the hillside on one side of the stream between the Upper Milo Diversion Dam and the existing Bunker Hill Reservoir. The grade would be slightly above the hydraulic grade of the stream, and the base of the slope would be reinforced with large riprap to protect the pipeline installation against erosion from the stream, if water were to bypass the Upper Milo Diversion dam. The pipeline would then discharge into a standard U.S. Bureau of Reclamation stilling basin. The overflow from the stilling basin would discharge into the existing Reed Landing Dam on Mainstem Milo Creek. The alignment for the South Fork Diversion pipeline is shown in Figure 1.

3.1.4 Costs

The cost analysis for the South Fork Diversion was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for the South Fork Diversion include:

- Design and construction of a South Fork Diversion structure, including the dam, foundation cutoff provisions (both a sheetpile wall and a grout curtain), intake screen, and transition structure.
- Design and construction of an upstream collector pipe and gabions
- Design and construction of a 2,200-foot pipeline

- Installation of a standard U.S. Bureau of Reclamation stilling basin at Reed Landing and near the crossing of Mainstem Milo Creek
- O&M costs include annual inspection, road maintenance, and pipeline and structure maintenance and repairs

Order of magnitude costs for the South Fork Diversion are summarized in Table 8 in Section 7. The costs for the South Fork Diversion are detailed in Attachment B of this technical memorandum.

4.0 Mainstem Milo Creek

This section presents the conceptual design and costs for the AMD mitigation measures that apply to the Mainstem Milo Creek drainage basin area. These measures include: Plug Small Hopes Drift, Remove Bunker Hill Dam, and Improve the Existing Upper Diversion Structure. Figure 1 shows the locations of these mitigation measures within the Mainstem. A description is provided for each mitigation measure, along with the design criteria, the conceptual design, and the costs (both capital and long-term O&M).

As discussed in the March 14 and 15, 2000, meeting with EPA and the State of Idaho, concrete lining/grouting of Mainstem Milo Creek from the upper diversion structure to the Reed Landing was identified as a potential option, but it was determined the technical feasibility is difficult and questionable because of the following:

- Steep hydraulic profile of the creek
- Uncertainties with underground mine workings and influence on lining construction and long-term O&M
- Ability to convey sidehill drainage into channel
- Influence and effects on existing improvements within the creek
- Impact of carrying bedload down to Reed Landing

It was, therefore, decided to not pursue this option at this time, but to possibly reconsider it in the future if further inflow reduction is needed.

4.1 Plug Small Hopes Drift

4.1.1 Description

Portions of the shallow Small Hopes workings that intercept flow from Mainstem Milo Creek would be located and plugged with a sand/cement grout or another suiTable material. In addition, vertical raises that connect the Small Hopes Drift with lower areas of the mine would be sealed with concrete to further control seepage into the mine.

4.1.2 Design Criteria

General design criteria for the cemented backfill option is as follows:

- Seal the old Small Hopes workings in a 75-foot section where it passes under the Mainstem of Milo Creek in order to reduce water infiltration into the lower areas of the mine
- Stabilize the workings from future collapse
- Minimize potential for water build-up, release, and flooding of lower-level workings

4.1.3 Conceptual Design

To construct this alternative, the old Small Hopes Drift would be relocated by survey methods in the field. The approximate location is shown in Figure 1. Access to the Small Hopes Drift would be re-established by constructing a vertical shaft adjacent to the Mainstem Milo Creek channel, or the shallow cave-ins and workings would be open-excavated as required to expose the remnants of the Small Hopes Drift. This work would be accomplished during a period when no water was flowing in the stream.

Once the drift had been opened, two raises that drop to lower levels of the mine would need to be located. These raises would then be cleaned out as required and plugged with concrete to prevent further infiltration of surface water into the lower workings of the mine. It is assumed that plugging the raises would require construction of a bulkhead in the raises; a concrete plug would be formed in rock above the bulkhead (assume 8 feet in diameter and 16 feet long). After the raises had been sealed, both ends of the old Small Hopes Drift would be bulkheaded off and a 75-foot section of drift under the creek would be backfilled with sand/cement backfill to seal the workings under the stream. The stream bed would then be restored over the top of the construction area. Figure 7 shows the anticipated cross section of the Small Hopes Drift and possible location of raises that extend to lower levels of the mine.

4.1.4 Costs

The cost analysis for Plugging the Small Hopes Drift mitigation was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest. Assumptions used in developing the cost estimate for this mitigation include:

- Performing a survey to determine the location of Small Hopes Drift
- Installing a new access drift to Small Hopes Drift
- Cleaning out Small Hopes Drift , locating two raises to 5 Level, and cleaning out and plugging shafts to 5 Level
- Transporting mix to pump site (including 3 to 4 percent cement)
- O&M costs include annual inspection and structure maintenance and repairs

Order of magnitude costs for Plugging the Small Hopes Drift mitigation are summarized in Table 8 in Section 7.

4.2 Bypass Bunker Hill Dam

4.2.1 Description

The Bunker Hill Dam is located downstream of the existing Upper Milo Diversion structure on Mainstem Milo Creek. The dam impounds water for diversion into an emergency drinking water supply pipeline for the town of Wardner. Figure 1 shows the location of the dam, which is in the vicinity of underground mine workings where impounded water is suspected to access these workings. Under this mitigation, the dam would be bypassed and the headworks of the dam modified.

4.2.2 Design Criteria

The following design criteria pertain to bypassing the Bunker Hill Dam structure:

- Remove water from the dam to minimize future infiltration of water into the underground workings through this area
- Maintain an area upstream of the existing dam to capture bedload
- Maintain an emergency water source for the town of Wardner

4.2.3 Conceptual Design

The location of the existing Bunker Hill Dam and existing pipeline are shown in Figure 1. Water is supplied to the dam at the present time by tee connection and valve on the stream diversion pipeline that feeds a small polyvinyl chloride (PVC) pipeline. Water is dumped into the small impoundment, and from there it is conveyed to the town via an existing pipeline down the hill beside the stream.

In this mitigation measure, the pipeline that currently diverts flow from the upper diversion to the Bunker Hill Dam would be extended and connected to the existing pipeline that conveys emergency water to the town of Wardner. The dam would be modified to maintain its capture of stream bedload during high flows in the spring. The outlet works of the dam would require the removal of the slide filter units and a section of the headwall to extend the upper diversion pipeline and connect with the existing water supply pipe. In addition, the hand-wheel-operated gate would need to be removed and an angled bar rack (grizzly) installed in its place. A concrete approach / anchor pad and a new concrete headwall extending over into the damaged section, where the filters would be removed, would also need to be constructed.

4.2.4 Costs

The cost analysis for bypassing the Bunker Hill dam was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

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- Extending the existing upper diversion pipeline and connection to the water line to maintain an emergency water supply for the town of Wardner
- Modify the outlet works of the dam for collection of debris and stream bedload

Order of magnitude costs for bypassing the Bunker Hill dam are summarized in Table 8 in Section 7. Costs for this mitigation measure are provided in more detail in Attachment B of this technical memorandum.

4.3 Improve Existing Diversion (Improve Seal/Decrease Overflow)

4.3.1 Description

The existing upper diversion structure on Mainstem Milo Creek would be improved to reduce the occurrence of overflow observed in the Mainstem below the structure. The location of this diversion structure is shown in Figure 1. This mitigation option would include (1) enlarging the screen diversion structure to increase the screen intake area and reduce clogging of the screen, (2) raising the weir to direct more flow into the pipeline (the current weir is designed to accommodate a 2-year flow event), and (3) installing an alluvial flow cut-off wall immediately downstream of the existing diversion. The alluvial flow cut-off wall will be constructed similar to the proposed West Fork Diversion structure alluvial cut-off as stated in Section 2.1A second option involving this structure includes significantly increasing the size of the water intake in the diversion, and increasing the sizing of the associated pipeline down to the second diversion structure to accommodate much larger flow events. This second option is discussed in Section 4.4.

4.3.2 Design Criteria

The following design criteria pertain to improving the existing diversion:

- Enhance the efficiency of the existing dam by minimizing overtopping of the weir during flows that are less than the design event, and capture alluvial flow that comes from drainage basin areas above the diversion location
- Establish a much larger intake capable of controlling the incidence of clogging at the intake screens
- Use the existing corrugated metal diversion pipeline
- Enhance the ability to clean the reservoir for periodic removal of sediment

4.3.3 Conceptual Design

For this alternative, it is assumed that the efficiency of diversion to the pipeline would be improved by establishing a larger, sloped screen intake structure and raising the weir on the dam to allow greater impoundment of water for diversion into the pipeline. This would be accomplished by constructing a new concrete diversion structure, screened grating, and associated improvements to the dam. Figures 8 through 11 show a concept for these improvements.

The existing corrugated metal pipeline would be reconnected to the new intake structure. A short hydraulic transition structure would be constructed to transition from the diversion structure to the corrugated metal pipeline.

The reservoir would be enlarged as a result of raising the dam. Currently the reservoir is sealed by use of a geosynthetic clay liner (GCL) under the area of the existing reservoir. It is assumed that the existing lining would be damaged by the new construction. The new, larger reservoir area would require enlargement of the lining system. Therefore, it is assumed that the base of the reservoir would be re-graded and that a new GCL would be provided under the impoundment area to help seal the bottom from leakage.

Good access to the reservoir would be provided so that the small reservoir area could be cleaned out on a regular basis. History has shown that Mainstem Milo Creek carries a significant bedload of sand, gravel, and rocks that must be cleaned out at regular intervals to assure that the diversion continues to function properly.

No other improvement would be considered with this alternative. More extensive diversion capacity and sediment control alternatives for this structure are discussed in Section 4.4 of this technical memorandum.

4.3.4 Costs

The cost analysis for improving the seal and decreasing the overflow of the existing diversion structure on the Mainstem of Milo Creek was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in development of the cost estimate for this mitigation include:

- Construction of approximately 600 square feet of steel screened inlet
- Raising the weir elevation of the existing dam up to 5 feet
- Construction for the improved diversion structure would require excavation, re-grading, and installation of a new concrete basin

O&M costs include annual inspection and structure maintenance and repairs, and screen / reservoir cleanout. Order of magnitude costs for seal improvement / overflow reduction at the existing Mainstem Milo Creek diversion structure are summarized in Table 8 in Section 7. Costs for decreasing the overflow of the existing Mainstem Milo Creek diversion structure are provided in Attachment B of this technical memorandum.

4.4 Improve Existing Diversion (Increase Pipeline Capacity)

4.4.1 Description

In this option, the size of the water intake in the diversion structure and the associated pipeline down to the second diversion structure (at the Reed Landing) would be increased

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to handle much larger flow events. The general location of the proposed pipeline routing is shown on Figure 1. In this alternative, the diversion structure and pipeline would be redesigned to accommodate the larger 10-year rainfall event with snowmelt flow as a design requirement.

4.4.2 Design Criteria

The following design criteria pertain to improving the existing Mainstem Milo Creek Diversion structure and increasing the discharge pipe sizing:

- Minimize overtopping of the weir during flows that are less than the design event
- Establish an intake capable of reducing the incidence of clogging at the intake screens
- Improve the blanket/cutoff under the dam and reservoir to minimize leakage under existing diversion to Mainstem Milo Creek
- Enhance the ability for cleaning the reservoir for removal of sediment
- Provide a new discharge pipeline to accommodate the 10-year rainfall event with snowmelt flow of 172 cfs as shown in Table 7

Surface Water Flow Estimates

Design flows were developed for Mainstem Milo Creek (Upper Milo Gulch) in the *Milo Gulch Flood Hydrology and Water Quality Improvement Plan* (Spectrum Engineering, 1996). The design flows include both rainfall events and rainfall events with snowmelt. These are summarized in Table 7.

4.4.3 Conceptual Design

For this alternative, more extensive modifications would be made to the existing upper diversion structure and diversion pipeline. The screen structure would be made much larger than the existing facility and the dam would be raised similar to the concept described in Section 4.3 (see Figures 8 through 11). A transition structure would be constructed to divert flow into a new HDPE pipeline 54 inches in diameter. The existing corrugated metal pipeline would be removed and the new pipe would be constructed along the same alignment.

In addition to all of the modifications described in Section 4.3, a perforated collector pipeline would be constructed in the Mainstem Milo Creek streambed upstream of the diversion structure. It is assumed that the perforated collector pipeline would be 36 inches in diameter and would be installed in a trench and backfilled with clean, poorly graded pea gravel to the streambed. It also is assumed that the collector pipe would be 450 feet long. The collector pipe would allow infiltration of most of the water in the streambed before it reached the diversion structure, thereby causing much of the sediment load in the streambed to drop out upstream with decreasing flow in the stream. Gabions would be constructed at regular intervals to help trap sediment and enhance infiltration to the collector pipe. The collector pipe would tap directly into the screen/diversion structure for conveyance to the new diversion pipeline.

4.4.4 Costs

The cost analysis for increasing the pipeline capacity of the existing diversion structure on Mainstem Milo Creek was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

- Increase capacity of the existing Mainstem Milo Creek diversion structure
- Construct grated concrete inlet structure
- Raise the weir of the existing dam
- Construct the upstream perforated collector pipe and gabions
- Remove the existing corrugated metal discharge pipeline
- Construct approximately 1,400 feet of HDPE discharge pipeline (52 inches in diameter) routed from the diversion structure down to the Reed Landing Dam
- Install standard U.S. Bureau of Reclamation stilling basins to dissipate water energy before water enters the Reed Landing Dam
- O&M costs include annual inspection, structure maintenance and repairs, and reservoir cleanout

Order of magnitude costs for increasing the pipeline capacity at the existing Mainstem Milo Creek diversion structure are summarized in Table 8 in Section 7. Costs for increasing the capacity of the existing Mainstem Milo Creek diversion structure are provided in more detail in Attachment B of this technical memorandum.

5.0 Deadwood Creek

This section presents the conceptual design and costs for the AMD mitigations that apply to the Deadwood Creek drainage basin area. A single mitigation is identified in Table 1 for Deadwood Creek, which is Plugging Inez Shaft. For this mitigation a description is provided, along with the design criteria, a conceptual design, and the costs (both capital and long-term O&M).

5.1 Plug Inez Shaft

5.1.1 Description

The Inez Shaft would be located and dug out down to competent bedrock and a plug would be constructed using concrete to reduce the water infiltrating into the mine workings from Deadwood Creek.

5.1.2 Design Criteria

Design criteria for plugging Inez Shaft include:

- Minimize leakage of water from both stream flow and alluvial groundwater flows in Deadwood Creek down the Inez Shaft
- Provide structural support for potential future loads to the shaft

5.1.3 Conceptual Design

Overburden soils have caved in around the entrance to the Inez Shaft. The shaft is located in Deadwood Creek along the east side of the stream. It is CH2M HILL's understanding that the old workings are located very close to the streambed and a direct correlation of inflow to the mine has been witnessed by miners as the flow in the stream increases.

This concept requires that the old shaft location first be determined by field survey methods. After the approximate location has been determined, a backhoe would be used to excavate into the overburden to confirm its location. Once the location can be determined, a braced sheet pile excavation would be constructed. The sheetpile would be dug and/or driven to bedrock and braced internally, as required. The sheet excavation would be centered on the shaft location. It also is CH2M HILL's understanding that the shaft extends down at about 30 to 45 degrees from vertical, sloping to the east. It is assumed that the shaft is about 6 to 8 feet in diameter.

Once the opening into the bedrock has been located, it would be cleaned out to expose a minimum length of competent rock in the walls of the shaft equal to about twice the diameter of the shaft. Bolting and shoring might be required for safety and support during the work. Next, a bulkhead would be constructed at the bottom and a Section of the shaft equal to twice the diameter of the shaft would be sealed with concrete to achieve a near water tight condition. After this was completed, the shoring would be removed and the area would be regraded. This alternative is shown in concept in Figure 12.

5.1.4 Costs

The cost analysis for plugging the Inez Shaft in Deadwood Creek was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

- Location of the Inez Shaft would require a field survey, then an excavation to verify the location
- A braced sheet pile excavation would be required
- The shaft is approximately 8 feet in diameter
- 16 feet of shaft would be excavated and cleaned out for plug preparation

- Once the concrete plug has been inserted, the stream bed would be regraded
- O&M costs include annual inspection of the area for caving

Order of magnitude costs for plugging the Inez Shaft in Deadwood Creek are summarized in Table 8 in Section 7. Costs for plugging the Inez Shaft are provided in more detail in Attachment B of this technical memorandum.

6.0 Other Areas

This section presents the conceptual design and costs for AMD mitigations that apply to other areas of the Milo Creek drainage basin area. Plugging drill holes is the only mitigation carried forward for other areas of the mine. For this mitigation, a description is provided, along with design criteria, the conceptual design, and the costs (both capital and long-term O&M).

6.1 Plug Drill Holes

6.1.1 Description

Drill holes on the 7 Level [Diamond Drill Hole (DDH) #1208] and in the Russell Tunnel, East Reed Drift, Bailey Drift, Van Raise, and Cherry Vent would be sealed by installing packers in the drill holes.

Another option includes collecting the clean water and piping it to a surface water drainage or to the treatment plant, depending on water quality. This second option might be necessary if attempts to plug drill holes resulted in increased infiltration in other areas of the mine.

6.1.2 Design Criteria

Design criteria for this mitigation option include:

- Pack drill holes to withstand 300 psi water pressure (200 psi maximum measured times safety factor of 1.5)
- Provide valving to vary flow from existing drill hole flow down to zero flow

6.1.3 Conceptual Design

This concept would be fairly easy to implement. It would require selected drill holes to be sealed to prevent water from directly contributing to drainage into the mine. The effectiveness of this alternative is unknown; plugging the drill holes might simply result in the water establishing other, less obvious flow paths into the mine through cracks and fissures, along fracture zones, or through other drill holes. However, if the rock formation is relatively tight, the plugging could significantly reduce the total flow from these sources.

The plugging would be achieved with mechanical packers, which would be inserted into the drill holes to an appropriate location. The packer would be seated by tightening it against the rock wall of the borehole. Use of a borehole camera would help establish suitable locations for each packer. Each installation would be provided with a central drain pipe and valve to allow flow past the packer until the packer could be seated against the rock.

NEXT

One or more of the drill holes are known to be operating under a considerable amount of pressure. In these areas, an anchor plate would be installed at the discharge point to assist in anchoring the packer assembly into the hole.

Careful monitoring would be required to assess whether the packers reduced the flow from various areas of the mine. Weirs and frequent monitoring for a period following the installation of the packers might be required to determine if the flows were increasing in other areas as a result of the plugging of drill holes. Monitoring is not included in the costs of this or any mitigation measures.

6.1.4 Costs

The cost analysis for plugging drill holes was performed on the basis of information contained in EPA guidance documents, experience in estimating similar projects, independent estimates, and engineering judgment. Order of magnitude estimates (plus 50 percent, minus 30 percent) have been prepared for capital implementation costs and for annual O&M costs. Capital implementation costs include engineering and construction management allowances. NPV for annual O&M costs are also included for a 30-year period at 7 percent interest.

Assumptions used in developing the cost estimate for this mitigation include:

- Adits would require clearing for access to the drill holes
- Twenty low-pressure drill holes and one high-pressure drill hole would require plugging
- O&M costs include annual inspection, maintenance, and repairs

Order of magnitude costs for plugging drill holes are summarized in Table 8 in Section 7. Costs for plugging drill holes are provided in more detail in Attachment B of this technical memorandum.

7.0 AMD Mitigations Cost Summary

Table 8 provides a summary of the proposed AMD mitigation options with their respective estimated costs. These costs are subject to the limitations described in Section 1.3 of this technical memorandum.

8.0 References

CH2M HILL, 2000a. *Draft Preliminary Screening for TMDL Compliance.* February. CH2M HILL, Spokane, Washington.

CH2M HILL, 2000b. *Supplement to the Draft Preliminary Screening for TMDL Compliance.* March. CH2M HILL, Spokane, Washington.

CH2M HILL, 2000c. *Bunker Hill Mine Water FS Alternatives.* June. CH2M HILL, Spokane, Washington.

CH2M HILL, 1999. *Bunker Hill Mine Water Presumptive Remedy*. July. CH2M HILL, Spokane, Washington.

Hunt, Joel. 1984. *Analysis of Recharge to an Underground Lead-Zinc Mine, Coeur D' Alene Mining District, Idaho*. September.

Spectrum Engineering, 1996. *Milo Gulch Flood Hydrology and Water Quality Improvement Plan*. March.

TABLE 1
Summary of Modifications to Original AMD Mitigations
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

AMD Mitigation Option	Modification
West Fork Milo Creek	
West Fork Diversion	• Increase the number of stilling basins along the pipeline's descent to Reed Landing • Changed position of confluence with Phil Sheridan pipeline
Phil Sheridan	• Separate the Phil Sheridan Diversion system mitigation options into Rehabilitating the Phil Sheridan Diversion and Improved Phil Sheridan Diversion Rehabilitation • Discontinue the option of conveying the collected water through the Phil Sheridan Adit • Construct a new drift that connects with the Phil Sheridan Adit for access to the Phil Sheridan Raises #1 and #2 and for pipeline installation for the Phil Sheridan diversion pipeline • Add the installation of a grout curtain for Raise #2 as an Improved Phil Sheridan Diversion Rehabilitation
Sidehill Diversions Above Guy Cave	None
Cemented Backfill into Homestake/Utz Workings	• Screened out as an ineffective alternative
South Fork Milo Creek	
South Fork Diversion	• A second U.S. Bureau of Reclamation stilling basin was added
Mainstem Milo Creek	
Remove Bunker Hill Dam	• Modified as bypassing the dam rather than removing the dam
Plug Small Hopes Drift	None
Improve Existing Diversion (improve seal, decrease weir overflow)	None
Improve Existing Diversion (increase pipeline capacity)	None
Deadwood Creek	
Plug Inez Shaft	None
Other Areas	
Plug Drill Holes	None

TABLE 2
Design Flows for West Milo Drainage Basin (From Spectrum, 1996)
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall w/ Snowmelt	Rainfall Only
2	6 cfs	0 cfs
5	17 cfs	2 cfs
10	34 cfs	4 cfs
25	53 cfs	8 cfs
100	86 cfs	28 cfs

TABLE 3
Design Flows for West Milo Diversion Structure (141 acres)
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall w/ Snowmelt	Rainfall Only
2	7 cfs	0 cfs
5	14 cfs	1 cfs
10	23 cfs	3 cfs
25	36 cfs	5 cfs
100	57 cfs	19 cfs

TABLE 4
Design Flows for Phil Sheridan Raises No. 1 and No. 2
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Raise No. 2 With West Fork Diversion In-Place (10.6 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	1 cfs	0 cfs
5	1 cfs	0 cfs
10	2 cfs	0 cfs
25	4 cfs	1 cfs
100	6 cfs	2 cfs
Raise No. 1 Without Sidehill Drainage Diversion (30.1 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	2 cfs	0 cfs
5	4 cfs	0 cfs
10	6 cfs	1 cfs
25	9 cfs	2 cfs
100	15 cfs	6 cfs

TABLE 5
Design Flows for Sidehill Diversion Ditches Alone and In Conjunction with Phil Sheridan Raise No. 1
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Sidehill Diversion Ditch Alone (22.2 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	5 cfs	0 cfs
5	7 cfs	1 cfs
10	10 cfs	3 cfs
25	13 cfs	6 cfs
100	19 cfs	11 cfs
Sidehill Diversion Ditch with Raise No. 1 (52.3 acres)		
Return Period (years)	**Rainfall w/ Snowmelt**	**Rainfall Only**
2	7 cfs	0 cfs
5	11 cfs	1 cfs
10	16 cfs	4 cfs
25	22 cfs	8 cfs
100	34 cfs	17 cfs

TABLE 6
Predicted Flows for the South Milo Creek Basin
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall with Snowmelt	Rainfall Only
2	11 cfs	1 cfs
5	40 cfs	4 cfs
10	76 cfs	8 cfs
25	118 cfs	22 cfs
100	186 cfs	70 cfs

(From Spectrum Engineering, 1996)

TABLE 7
Design Flows for Upper Milo Gulch Drainage Basin
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

Return Period (years)	Rainfall w/ Snowmelt	Rainfall Only
2	37 cfs	3 cfs
5	105 cfs	12 cfs
10	172 cfs	33 cfs
25	251 cfs	83 cfs
100	376 cfs	184 cfs

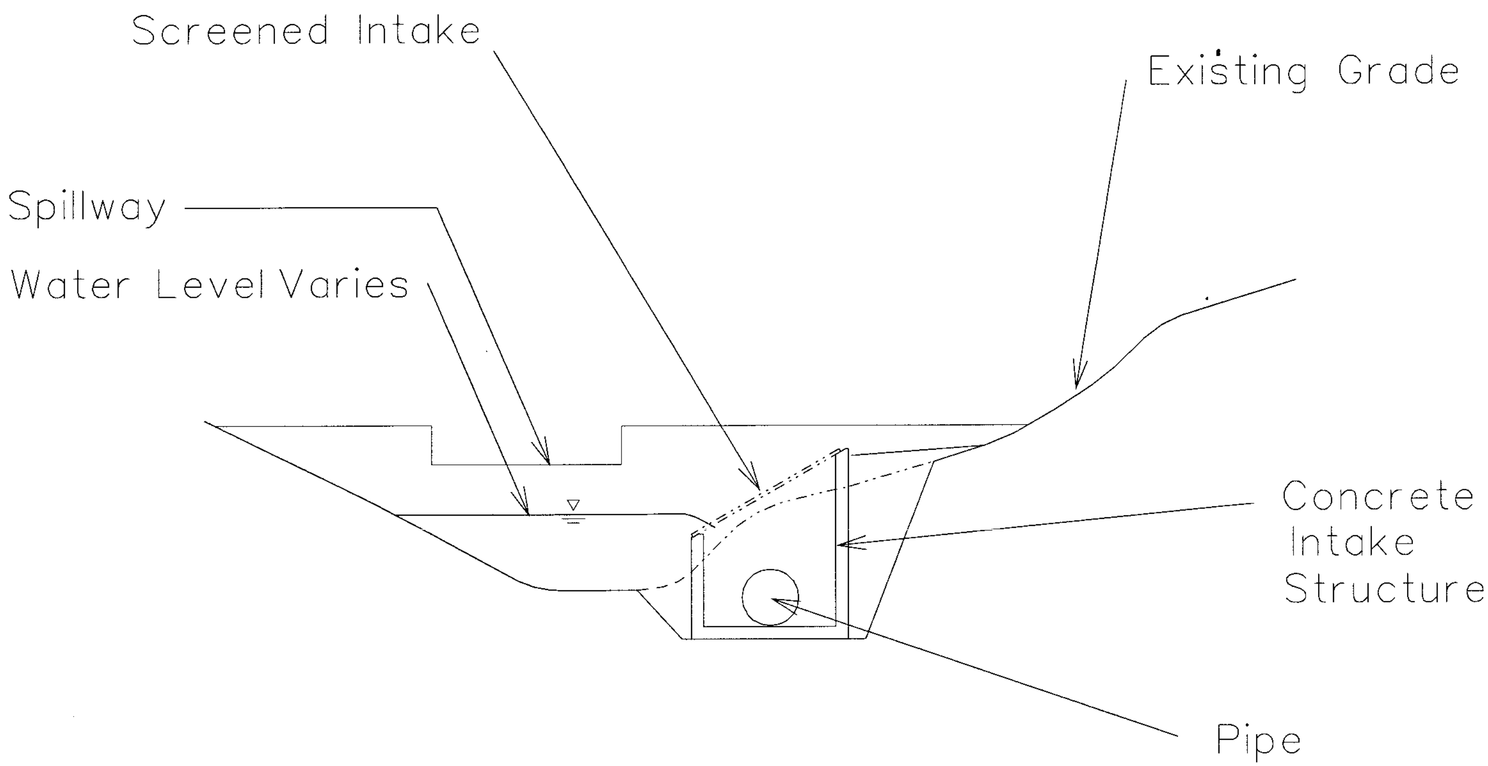
(From Spectrum Engineering, 1996)

TABLE 8
AMD Mitigations Cost Summary
Mitigation/Treatment Evaluation – Bunker Hill Mine Water Management

AMD Mitigation Option ($)	Capital Cost ($)	Annual O&M Cost ($)	Total 30-year Present Worth Cost[1] ($)
West Fork Milo Creek			
West Fork Diversion	3,590,000	27,700	3,934,000
Rehabilitate Phil Sheridan Diversion	1,250,000	18,200	1,476,000,
Improve Phil Sheridan Diversion Rehabilitation	380,000	500	386,000
Sidehill Diversions above Guy Cave	490,000	11,700	635,000
South Fork Milo Creek			
South Fork Diversion	1,870,000	29,900	2,241,000
Mainstem Milo Creek			
Plug Small Hopes Drift	360,000	500	366,000
Bypass Bunker Hill Dam	60,000	24,300	362,000
Improve Existing Diversion—Improve Seal/Decrease Flow	590,000	99,300	1,822,000
Improve Existing Diversion—Increase Pipeline Capacity	2,670,000	99,300	3,902,000
Deadwood Creek			
Plug Inez Shaft	650,000	500	656,000
Other Areas			
Plug Drill Holes	150,000	9,200	264,000

[1]Total 30-year present worth of capital cost and net present worth at 7 percent interest.

NEXT



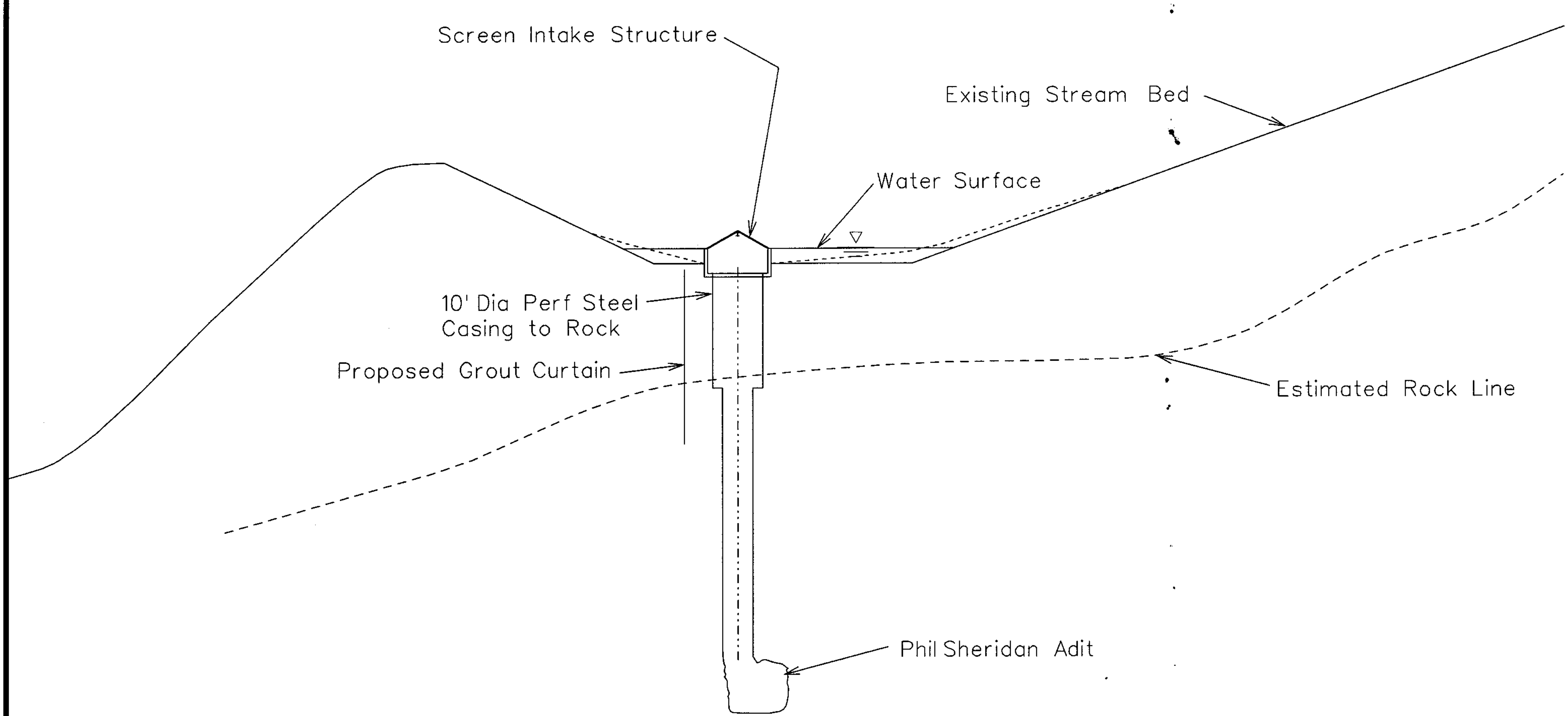
TYPICAL SECTION
1" = 10'

- WEST FORK -
DIVERSION STRUCTURE SECTION

FIGURE 4

CH2MHILL

NEXT

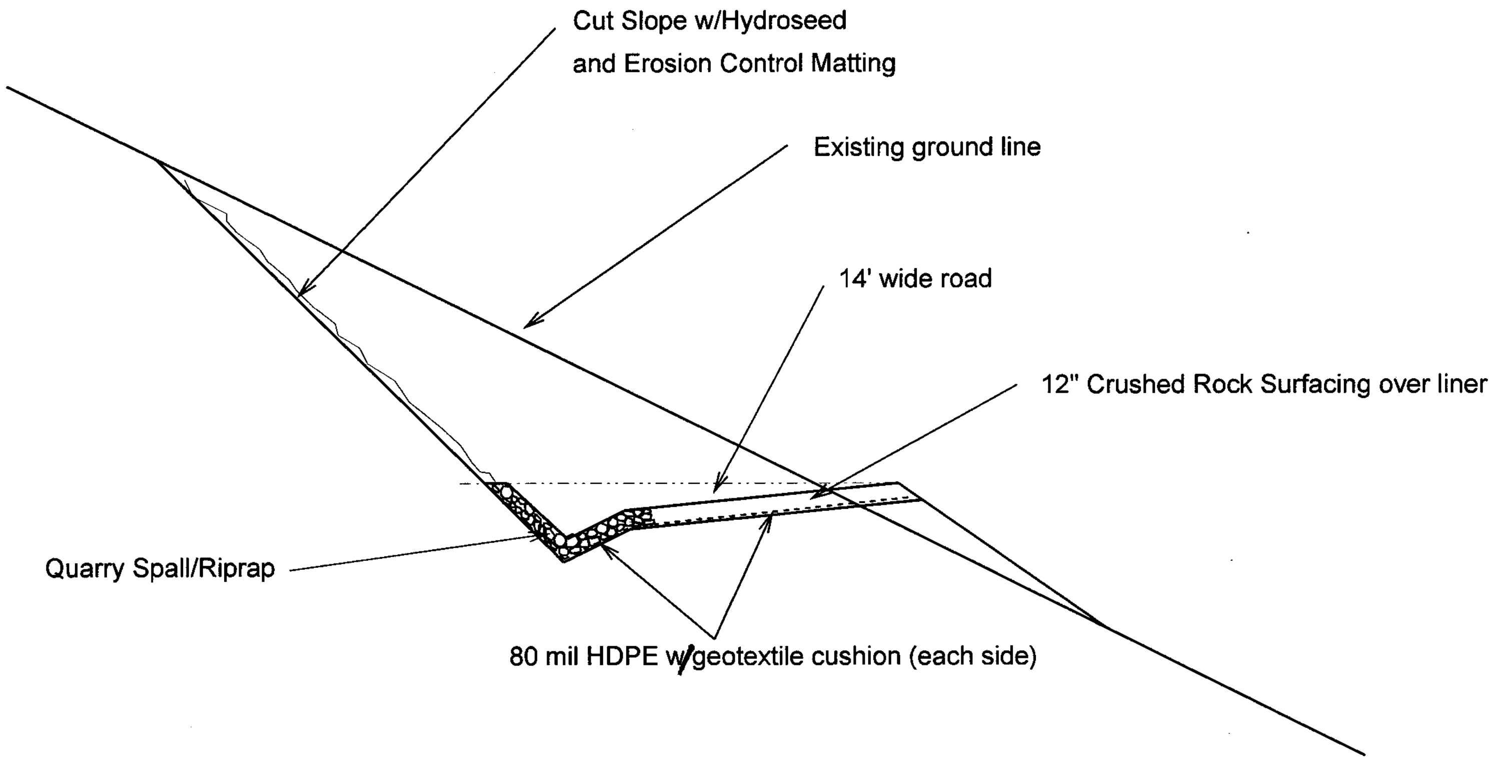


RAISE #2 DIVERSION STRUCTURE
Scale: 1" = 30'

FIGURE 5

CH2MHILL

NEXT



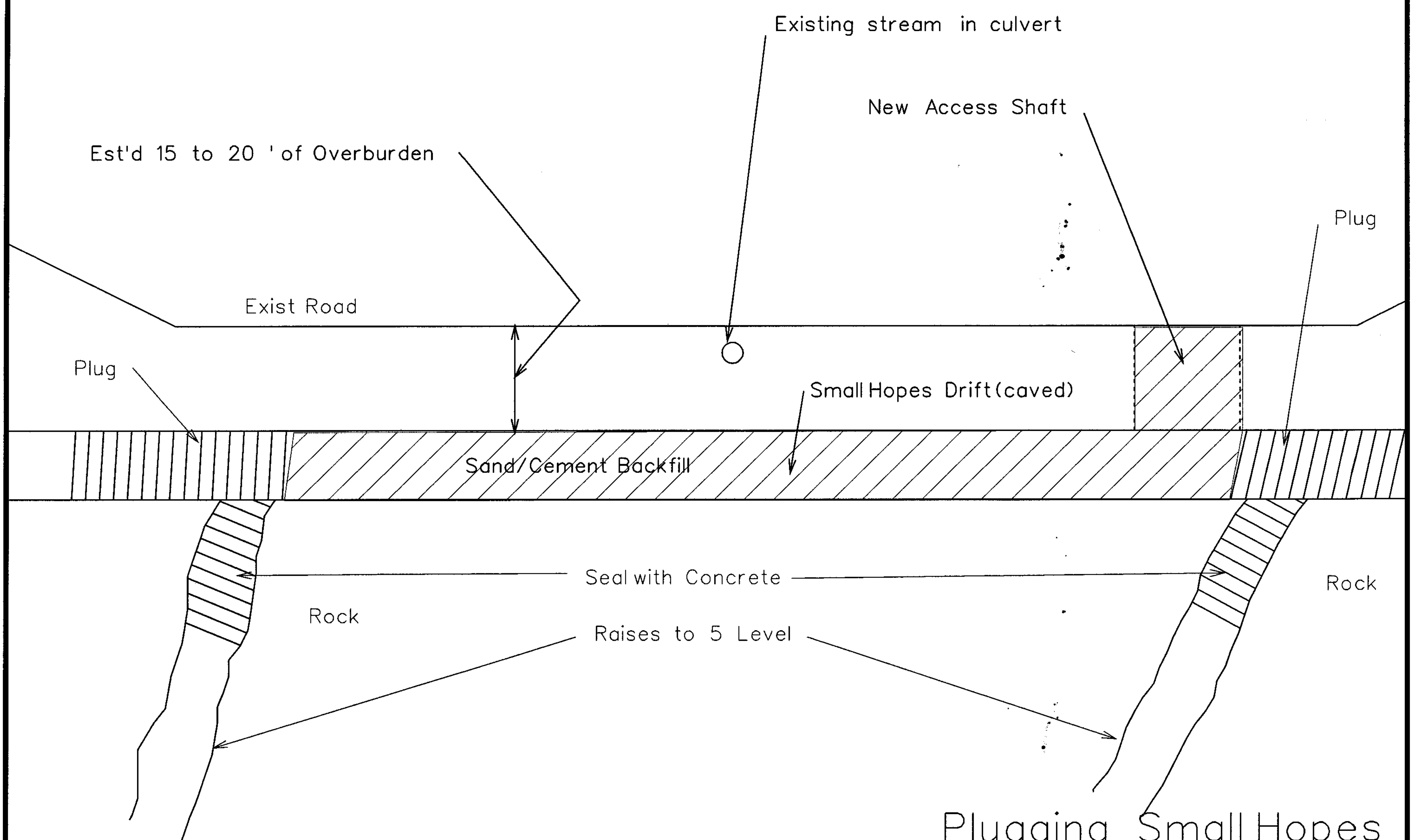
SIDEHILL DIVERSIONS ABOVE
GUY CAVE INTERCEPTOR
DITCH SECTION

1" = 10'

FIGURE 6

CH2MHILL

NEXT

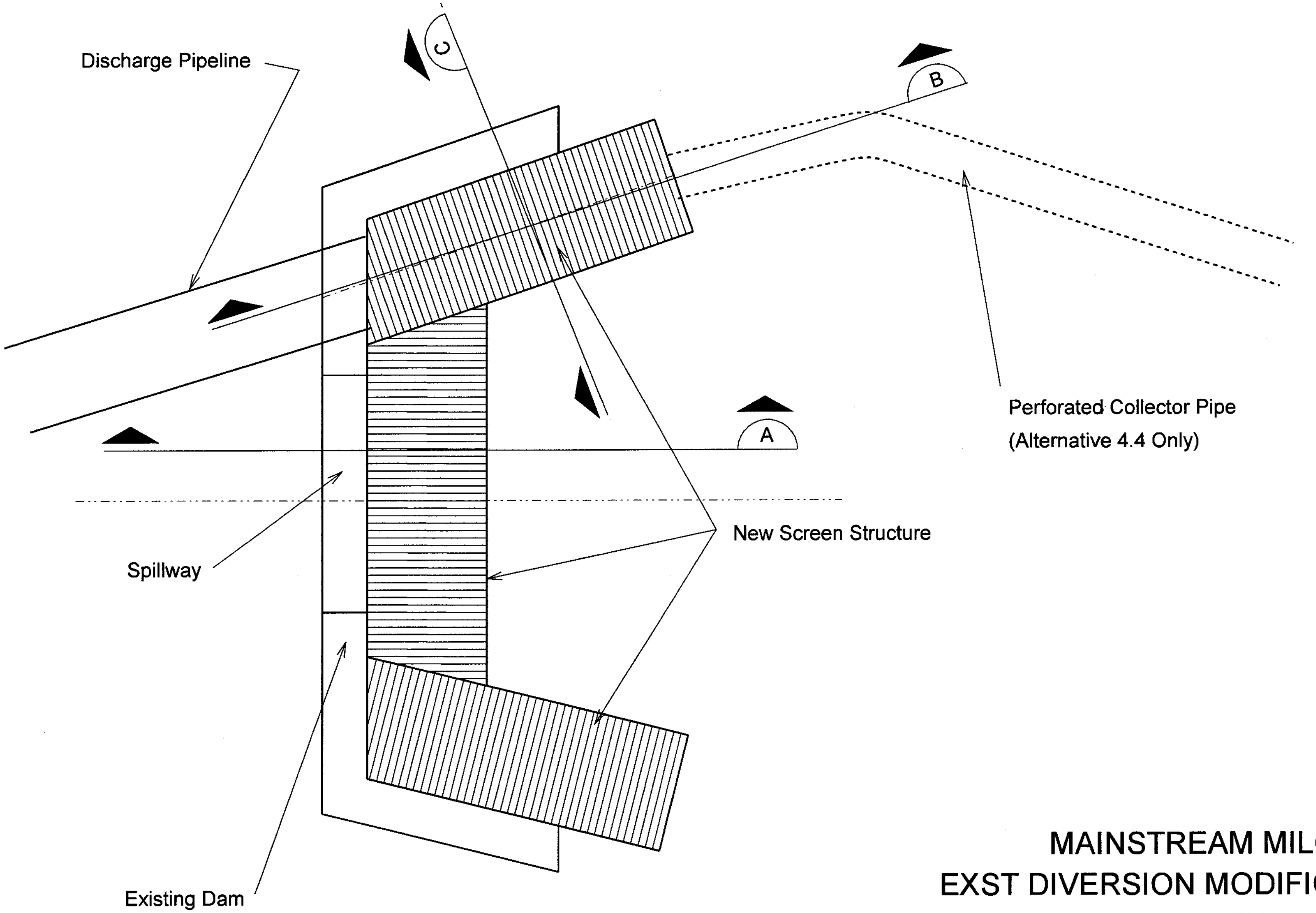


Plugging Small Hopes
1" = 20'

FIGURE 7

CH2MHILL

NEXT



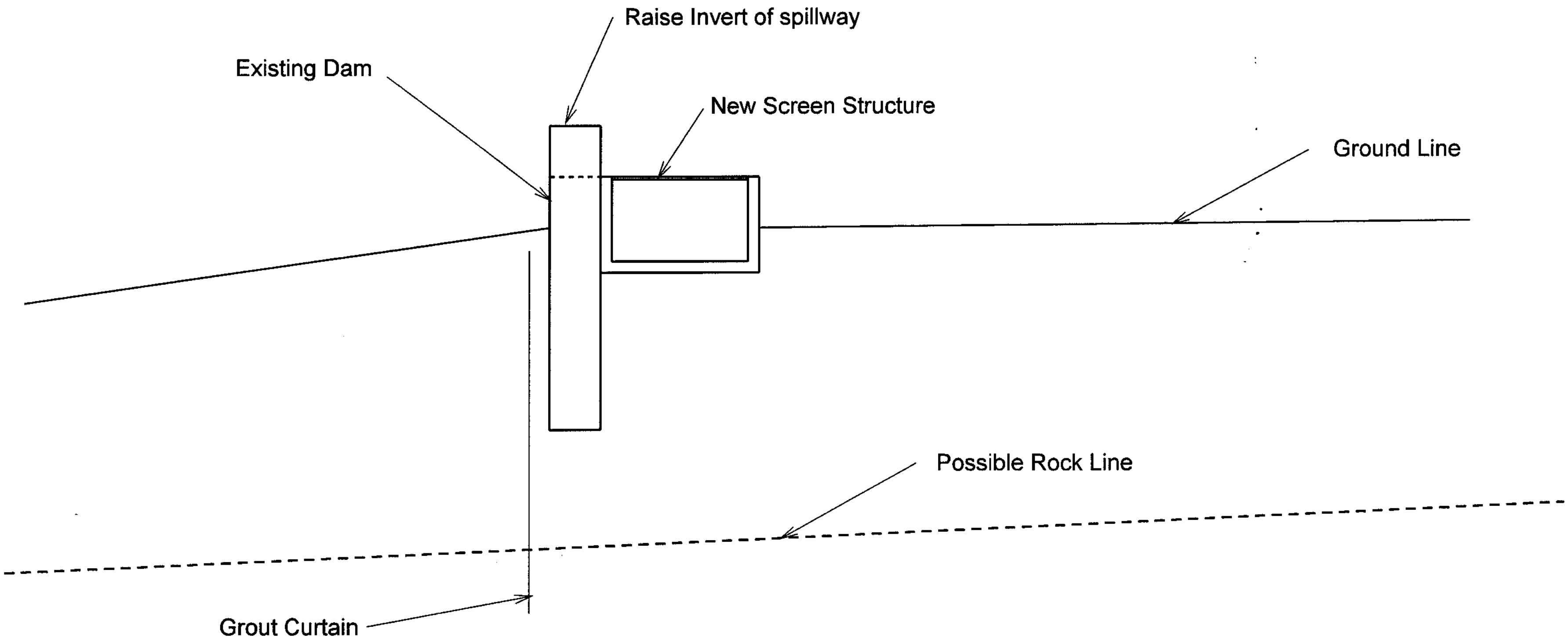
SCREEN STRUCTURE
UPPER DIVERSION
1" = 10'

MAINSTREAM MILO
EXST DIVERSION MODIFICATIONS
- PLAN VIEW -

FIGURE 8

CH2MHILL

NEXT



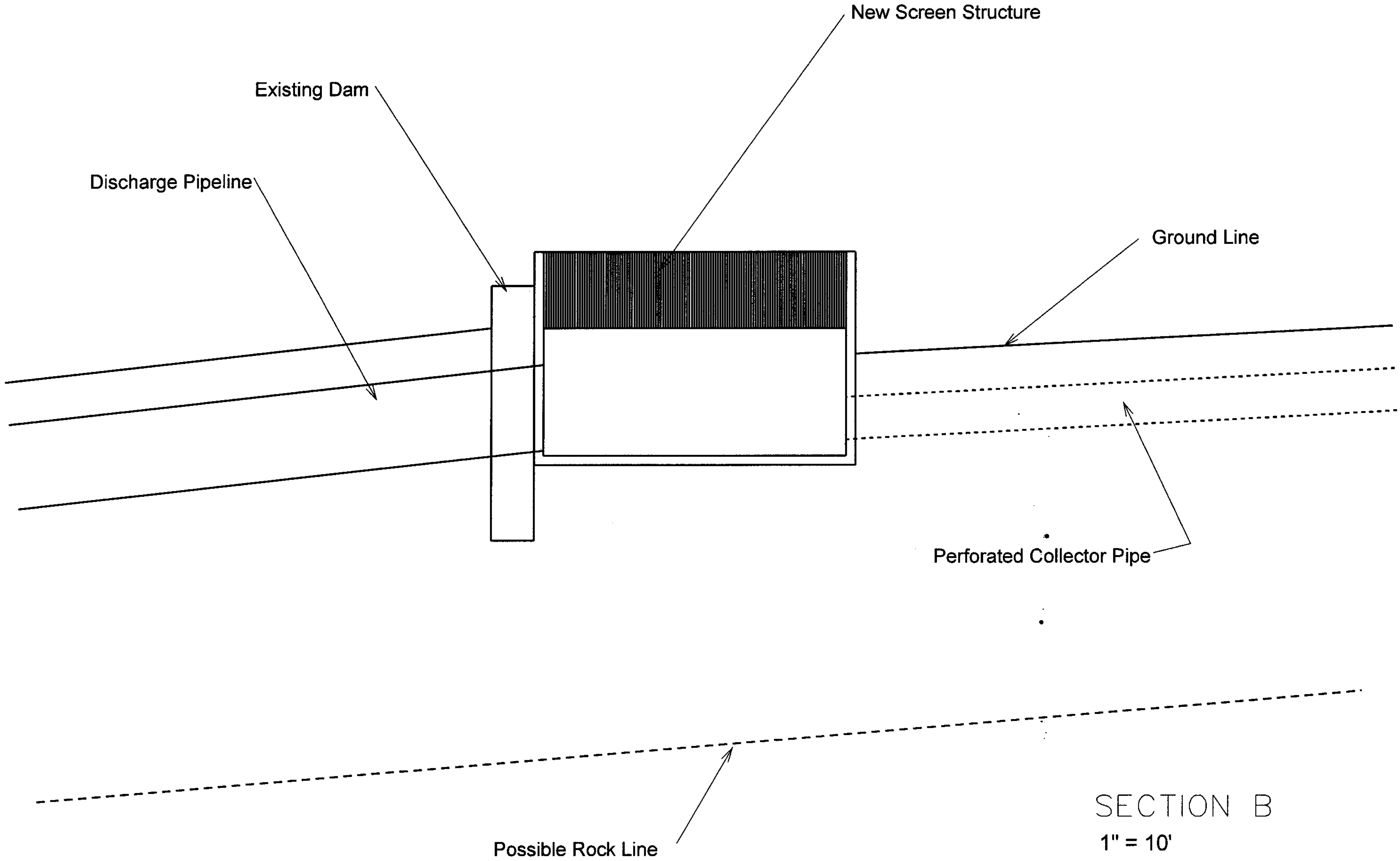
SECTION A

1" = 10'

FIGURE 9

CH2MHILL

NEXT

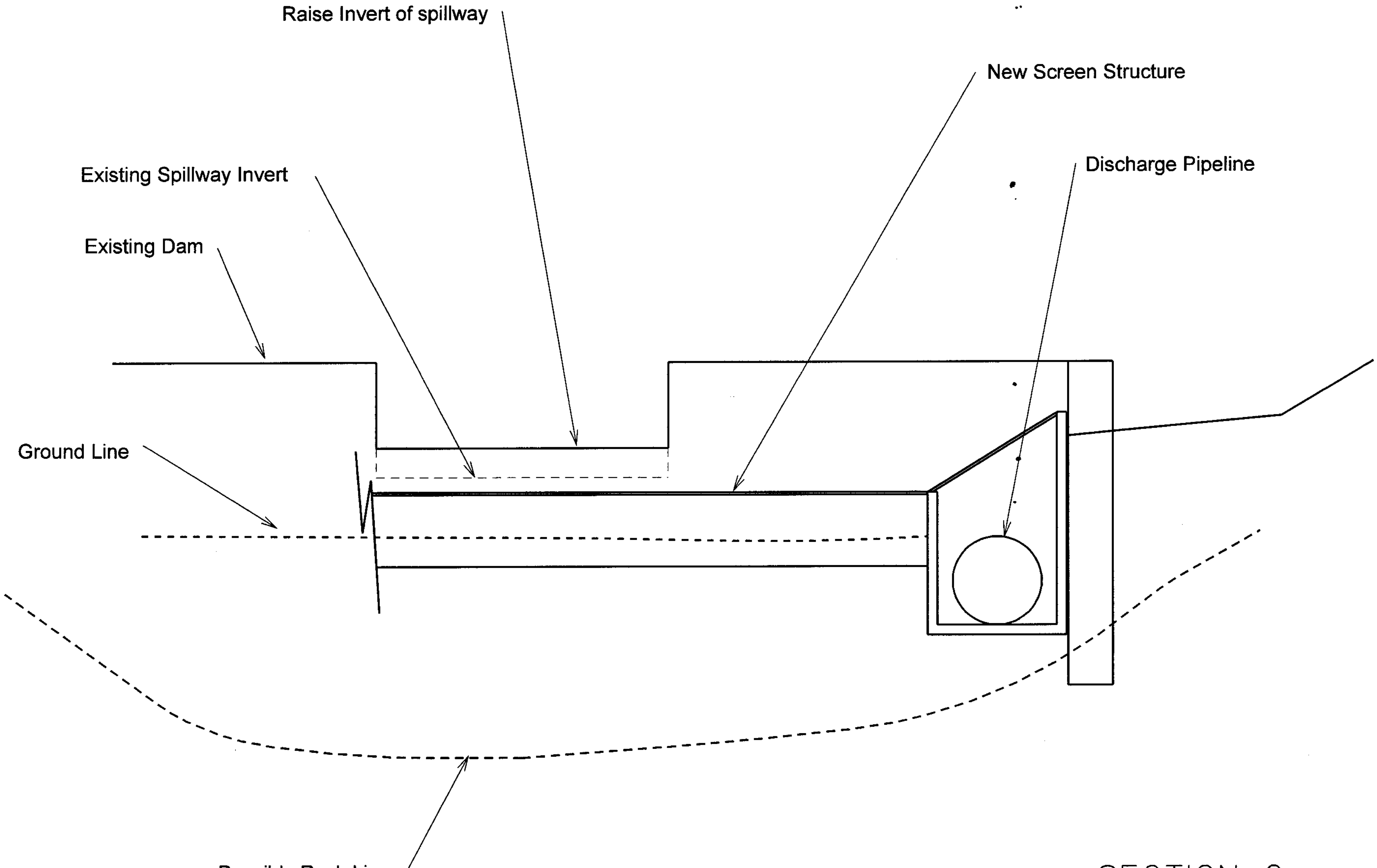


SECTION B
1" = 10'

FIGURE 10

CH2MHILL

NEXT



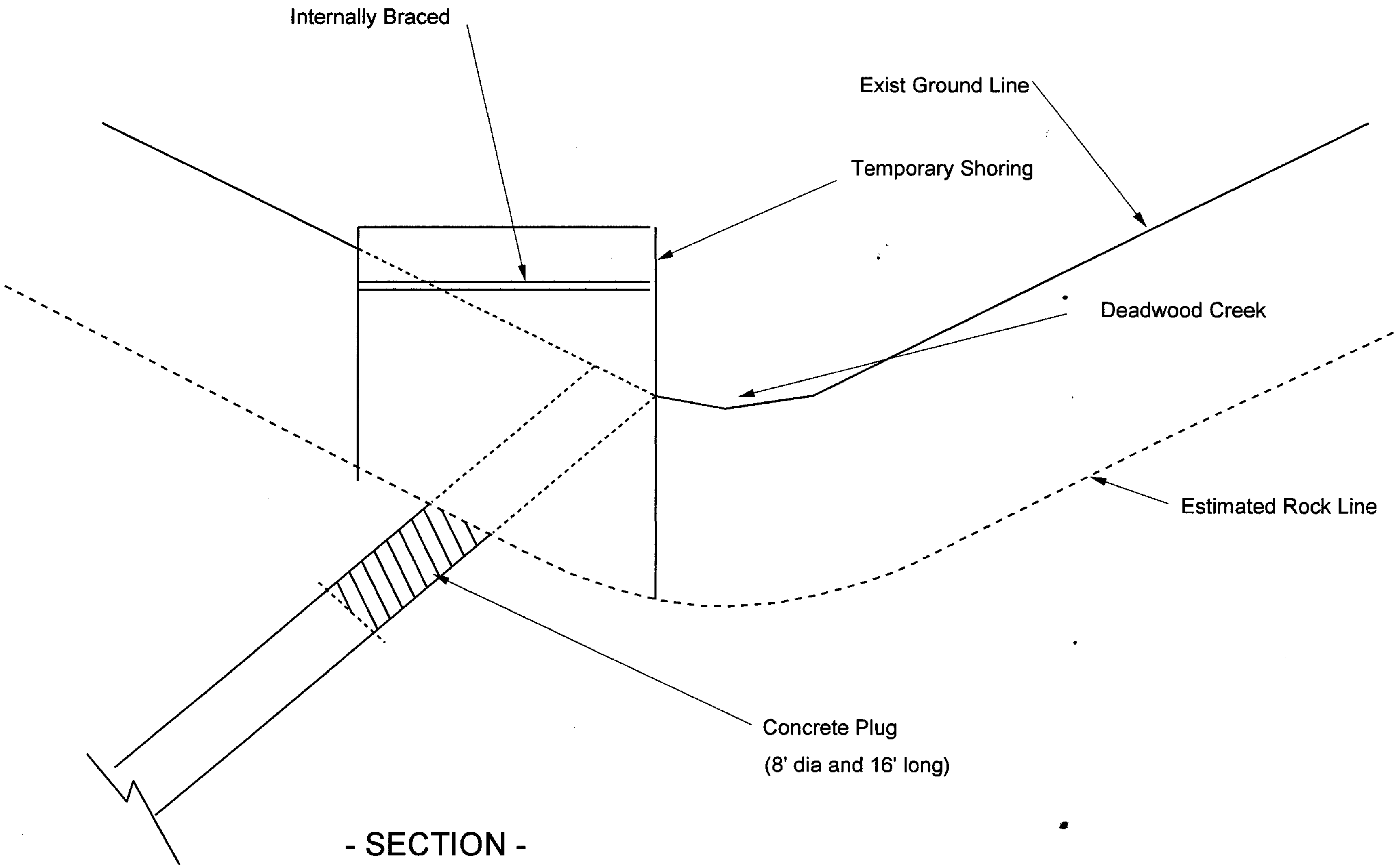
SECTION C

1" = 10'

FIGURE 11

CH2MHILL

NEXT



- SECTION -

1" = 20'

PLUGGING OF INEZ SHAFT

FIGURE 12

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